Climate Divisions for Alaska Based on Objective Methods

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Main Results

- 13 climate divisions in Alaska, difficult to draw the lines with sparse stations
- AO, NPI, PNA, PDO and EP/NP have seasonal links with divisional average temperatures
- May be possible to calculate division average temperature anomalies 1920-present

Motivation and Background

- Alaska climate regions first drawn by Fitton (1930) [Fitton]
- Divisions outlined by Searby (1968) currently used by the National Climatic Data Center [NCDC]
- Climate regions updated by Shulski and Wendler (2007) [ACRC]
- None are based on primarily objective methods
- Useful for seasonal forecasting and many other research applications

Divisions work from Bieniek et al. (2012)

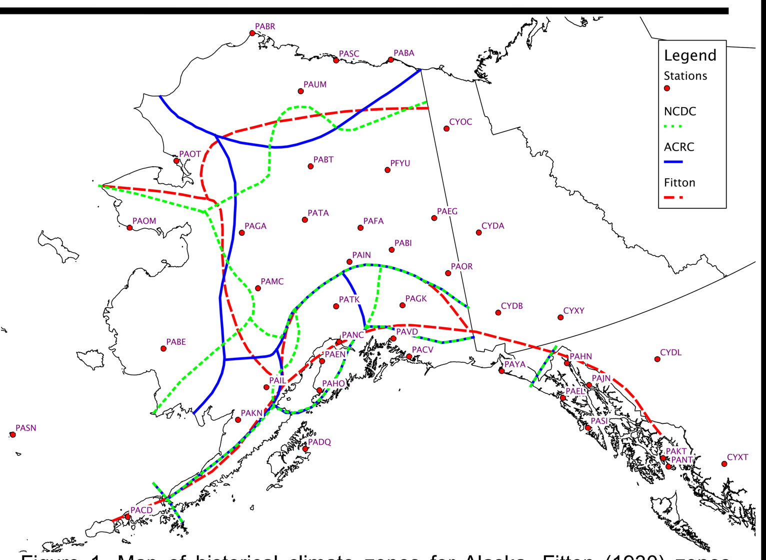


Figure 1. Map of historical climate zones for Alaska. Fitton (1930) zones outlined by red dashed, National Climate Data Center (NCDC) climate divisions green dashed, and the Alaska Climate Research Center (ACRC) climate regions solid blue lines, respectively. The stations used in the development or our divisions are shown as purple dots with their respective airport code. The climate zones have undergone only minor revisions since their inception, and are mainly drawn over major terrain features.

Data and Methodology

Station temperature and precipitation (1977-2010) obtained from:

- National Climatic Data Center (NCDC)
- National Weather Service (NWS)
- Environment Canada
- Alaska Climate Research Center
- Global Summary of the Day (GSOD)

Analysis:

- Missing data filled with adjusted AVHRR satellite temperature at pixel nearest the each station when possible
- Data processing (e.g. Wolter and Allured 2007)
- Cluster Analysis: Wards, Average Linkage and K-Means methods

Clustering identified 13 divisions in Alaska/Canada

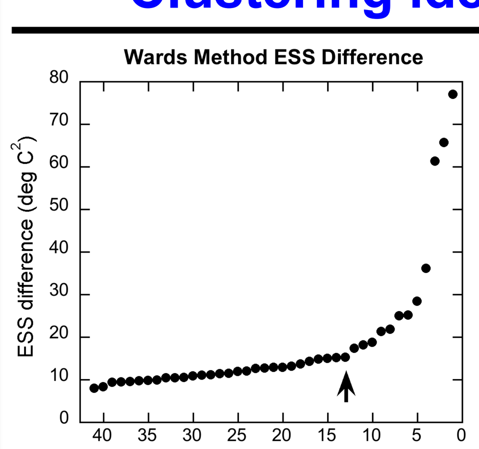


Figure 2. Error Sum of Squares (ESS) difference from step to step as shown in black dots for the Wards method cluster analysis of station temperature for 1977-2010. An arrow marks where the optimal number of clusters was selected for our data (13 clusters).

- <u>Precipitation found to be too localized/sparse for clustering; temperature used alone</u>
- The distance between clusters or error sum of squares (ESS) increases faster after 13 clusters are formed
- Stopped at 13 clusters: 11 Alaska, 2 entirely in Canada

- Three methods had generally consistent results
- Stations appear somewhat clustered about terrain
- Most discrepancies in southeast and south-central coastal stations
- How to draw lines with such sparse data?

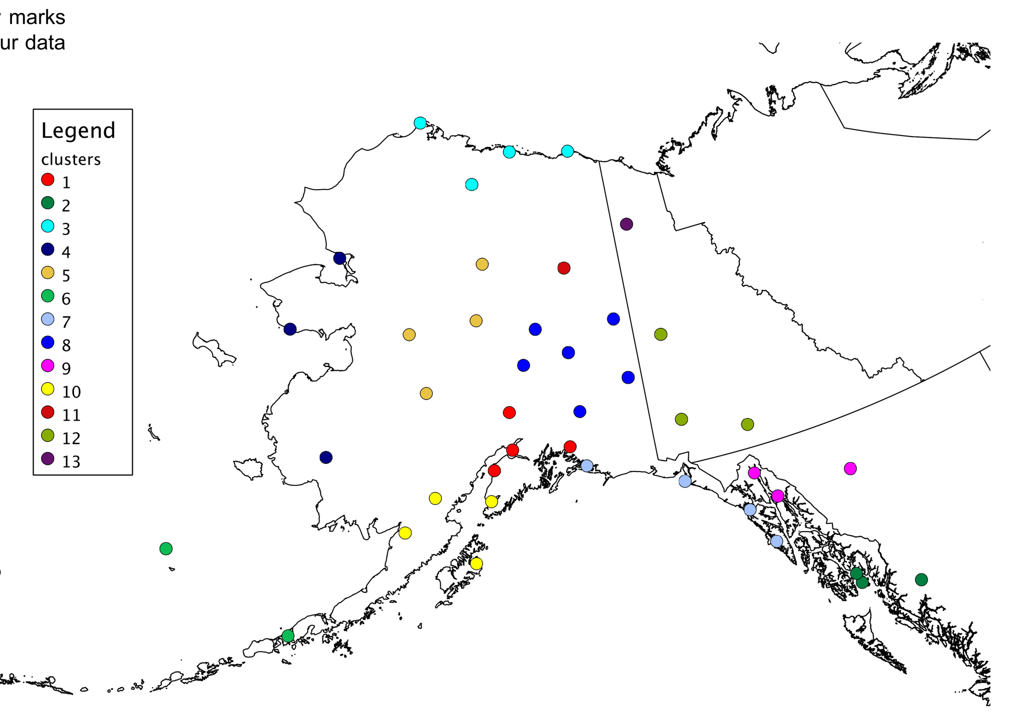


Figure 3. The 13-cluster solution from the Ward's method cluster analysis of station temperature. Dots are color-coded by their cluster membership. There are 11 clusters in Alaska with 2 entirely in Canada. The stations appear to group around major terrain features.

Where should the lines be drawn?

- Terrain features appear to have strong influence on the locations of the divisions
- Division boundaries refined aided by local expert knowledge of experienced weather forecasters
- Cross-correlation checks of the station data supported the divisions selected

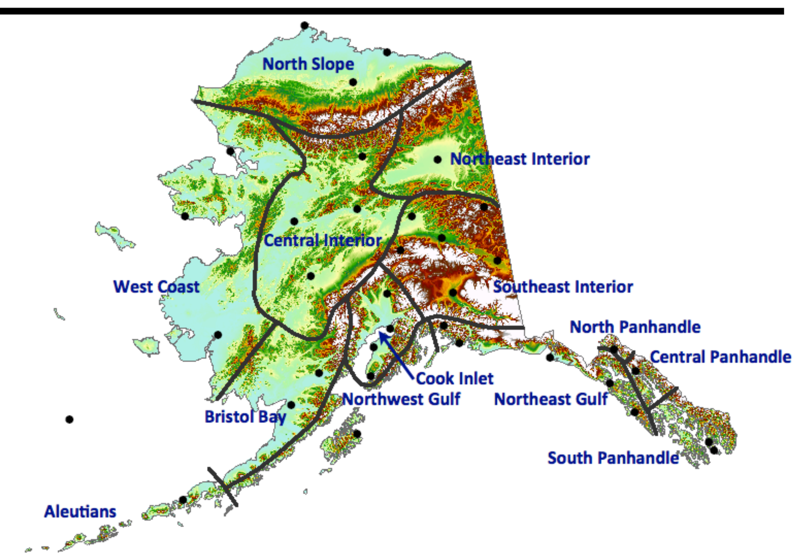
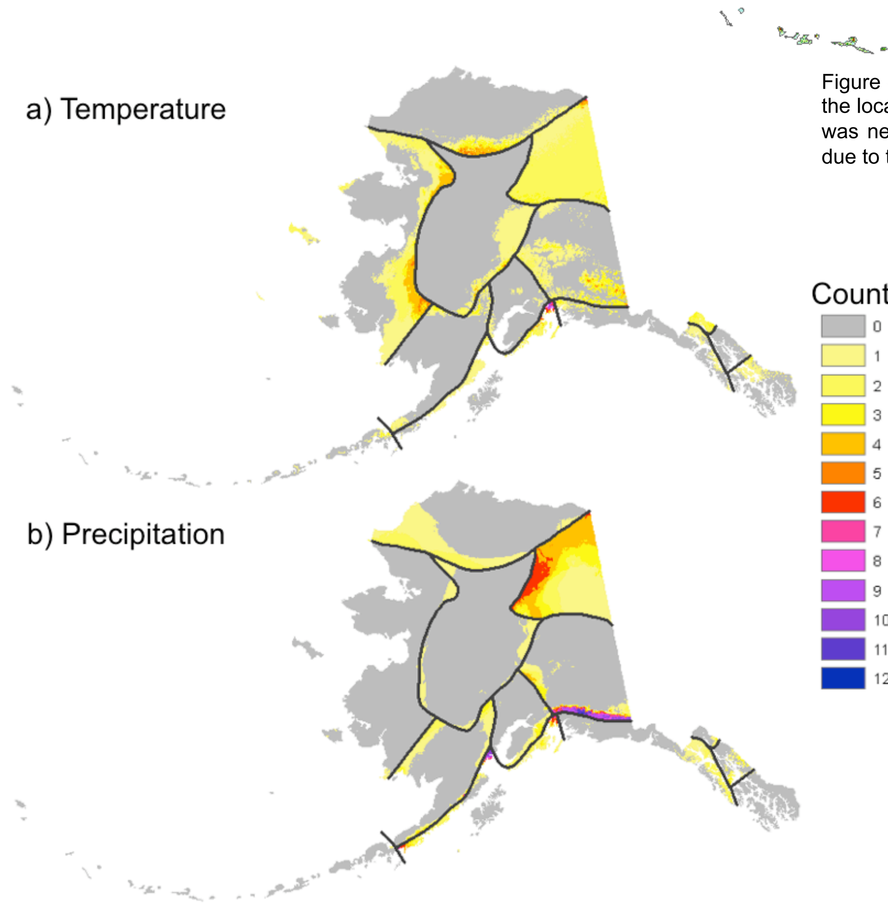


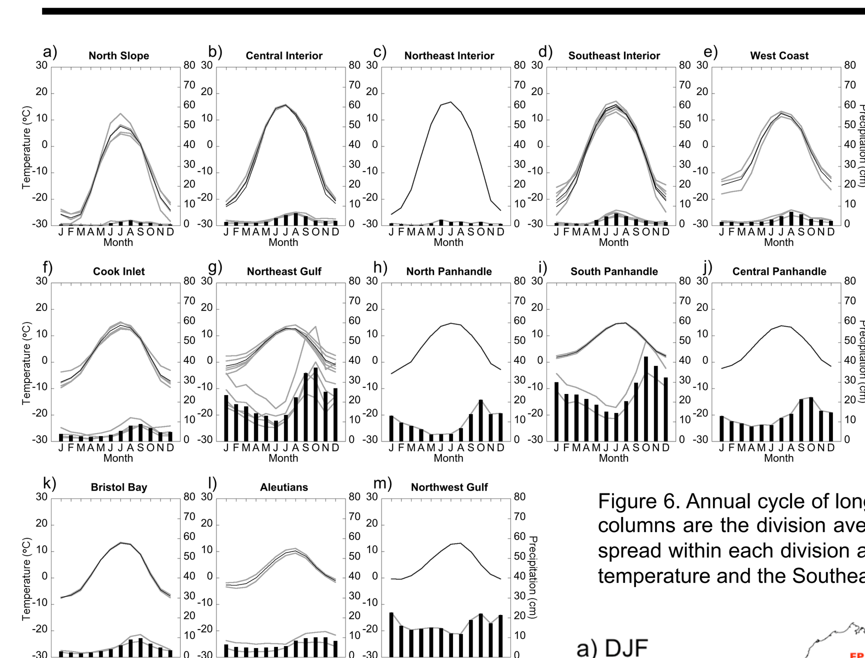
Figure 4. Climate division boundaries drawn over Alaska topography. Black dots show the locations of the Alaska stations used in the cluster analysis. Human expert analysis was necessary to draw these lines, as no effective objective method could be found due to the sparse station network available for clustering.



- Boundaries tested using monthly downscaled temperature and precipitation (Hill and Calos, 2011)
- Division average station temperature and precipitation correlated with each point
- Counts > 0 indicate pixels that correlated higher with divisions other than their own
- Most areas correlated best with their own division average temperature and precipitation

Figure 5. Counts of when a point was correlated higher with another division average than its own for (a) temperature and (b) precipitation. Higher counts indicate that multiple division averages had higher correlations than when the point was correlated with its own division average. Most areas correlate best with their own divisions.

Climates of the divisions



- Stations within each division have similar climate characteristics
- Little spread in monthly mean temperature and precipitation

Figure 6. Annual cycle of long-term monthly mean temperature (lines) and precipitation (columns). Black lines/columns are the division average and the grey lines are the individual station long-term means. There is little spread within each division and the annual cycles have the same shapes. NE interior has the largest range in temperature and the Southeast coast/Annette both are the wettest divisions in Alaska.

- Division average temperature have seasonal links with major teleconnection indices:
  - AO, PDO, EP/NP, NPI, PNA

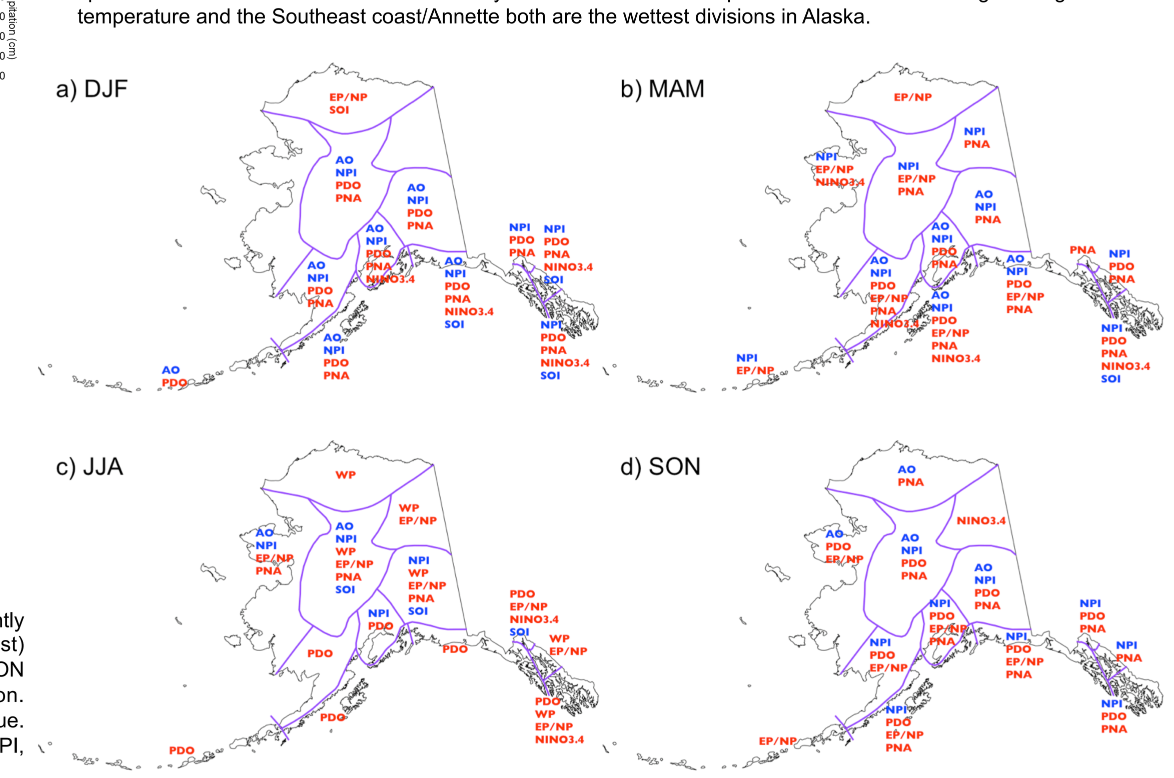


Figure 7. Teleconnection indices that were significantly (95% level or greater based on Student's t-test) correlated with (a) DJF, (b) MAM, (c) JJA, and (d) SON seasonal average temperatures for each division. Positive/negative correlations are shown as red/blue. The most common correlations occur with the AO, NPI, PNA, and PDO.

Constructing division averages for climate analysis

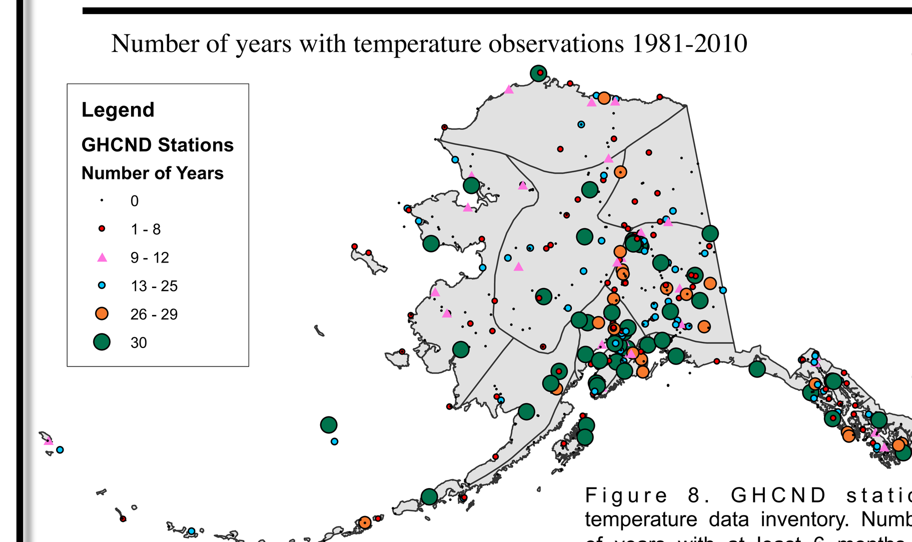


Figure 8. GHCND station temperature data inventory. Number of years with at least 6 months of temperature data 1981-2010 shown as graduated symbols.

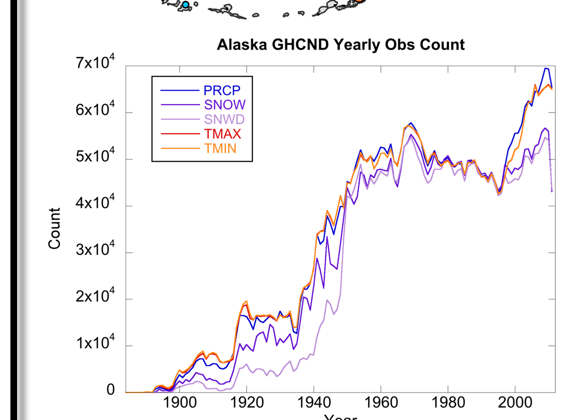


Figure 9. Number of observations per year at all GHCND stations in Alaska. Variables are total precipitation, average snow fall, snow depth, maximum and minimum temperature.

- The Global Historical Climatology Network-Daily (GHCND) is being investigated to create an extended time series of monthly data for each division suitable for analysis and prediction
- The number of stations varies greatly by division

- Observations are sparse prior to the 1950's
- Monthly divisional time series of temperature anomalies 1920-present seem possible
- Regression analysis appears to be useful to fill data gaps
- Do stations that come and go impact trends and variability?

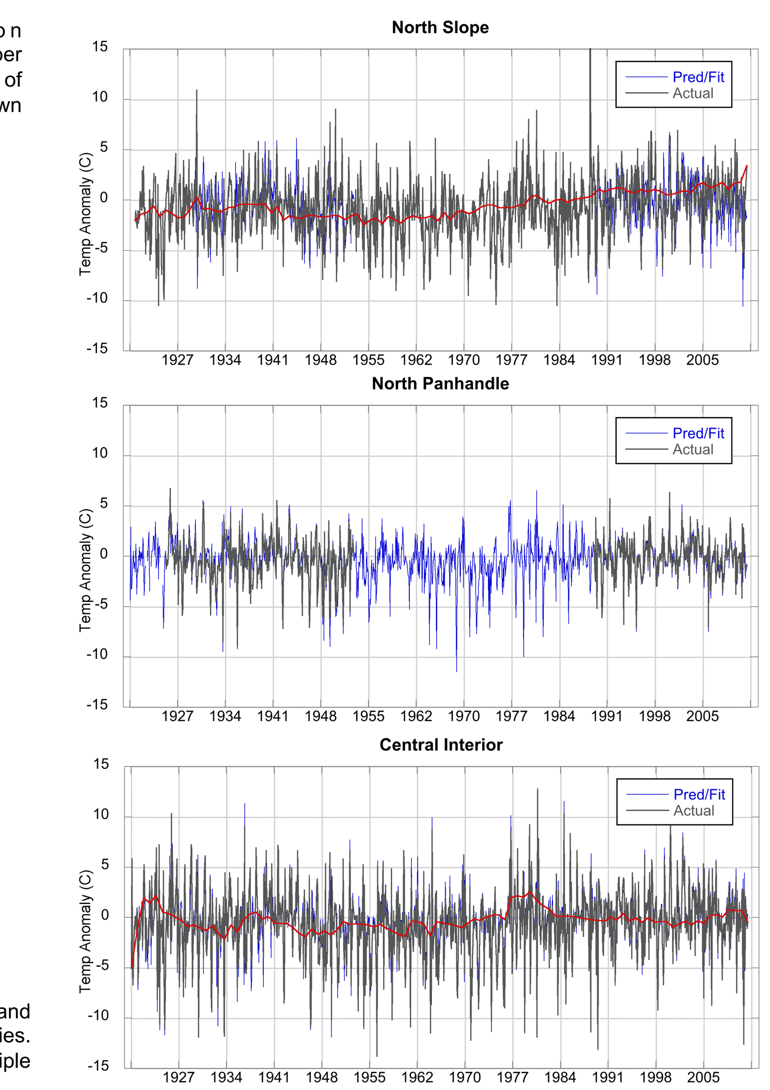


Figure 10. Monthly divisional average anomalies for the North Slope, North Panhandle and Central Interior Alaska climate divisions. Gray/blue lines show the observed/predicted anomalies. 5-year running mean of observed anomalies shown as red line. Predicted values are from multiple regression models based on the neighboring climate division anomalies.

Summary and Conclusions

- 13 climate divisions in Alaska with terrain marking the boundaries
- For Alaska, a mix of objective and subjective methods are necessary to best delineate climate divisions
- Stations within each division had similar climate types/regimes
- A diverse set of teleconnections impacts each division differently in each season
- Time series of divisional temperature anomalies 1920-present are plausible

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